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A method for overcurrent protection in a superconducting cable.

The invention relates to a method for overcurrent protection in a superconducting cable, comprising a current detector, which is inserted in series with the cable conductor of the superconducting cable

Furthermore, the invention relates to a superconducting cable, wherein the cable conductors of the cable are connected in series with a current detector for overcurrent detection.

When using superconducting cables in a high-voltage system, it is important that said cables are protected from overcurrents since the result of overcurrents in the cable conductor of a superconducting cable is loss of superconductivity thereof. This means that the cable could soon be exposed to destruction, since the superconducting tapes conducting the current are not at all adapted to transmit large currents, when they are not superconducting.

A typical requirement for a superconducting cable is that it should be protected from overcurrents. This protection requirement may e.g. be that the cable should be able to withstand approximately 40 kA for 1 second.

JP 01 039230 discloses a method for protecting a superconducting cable against overcurrent by inserting a current detector in series with the cable conductor.

The object of the invention is now to provide a method for protecting a superconducting cable, accommodating the requirements stipulated above.

The objective of the invention is fulfilled by a method of the type defined in the preamble of claim 1, the method being characterized in that an electrical conductor is inserted in parallel with the cable conductors of the superconducting cable and the current detector.

Hence, constant monitoring of the current in the superconducting cable during operation is ensured, so that if the current exceeds some predetermined limits, the current will be broken or limited prior to a destructive, heavy heating of the cable. Thus, when the superconducting state ceases, the current is allowed to be diverted in the hot shunt.

As indicated in claim 4, that the current detector constitutes at least one superconducting piece, reliable overcurrent detection is obtained, since the superconducting pieces - if exposed to a current that is too high - exit their superconducting state, causing an intense generation of heat in the superconducting pieces.

This generation of heat can then be used if, as inter alia indicated in claim 6, a fuse is inserted as a circuit breaker to break the current to the cable conductors of the superconducting cable.

With a view to accommodating the time delay in a circuit breaker, specifically the inevitable time delay defined by the period of time necessary for breaking a current by means of a circuit breaker, it is advantageous, as indicated in claim 8, to a cold shunt is inserted in parallel with the cable conductors of the superconducting cable The cold could be designed to be capable of carrying e.g. 40kA in 0.1 second.

It is noted that the for diversion of the current to the superconducting cable after the above-mentioned 0.1 second has elapsed, then the electrical conductor is preferably inserted.

Additional appropriate embodiments of the method are set out in claims 2,3,5 and 7.

As already mentioned, the invention also relates to a superconducting cable wherein the cable conductors of the cable are connected in series with a current detector for overcurrent detection

This cable is of the type defined in the preamble of claim 9 and is characterised in that an electrical conductor is inserted in parallel with the cable conductors of the superconducting cable and the current detector.

Appropriate embodiments of the cable are set out in the independent claims 10-14.

In the following, the invention will be discussed in greater detail with reference to an exemplary embodiment shown in the drawings in which:

Fig. 1 shows a basic construction of a superconducting cable with overcurrent protection according to the invention,

Fig. 2 shows a more detailed construction of an embodiment of the cable with overcurrent protection according to the invention,

Fig. 3 shows the relationship with respect to time between currents flowing in the cable according to Fig. 2 in an overcurrent situation, whereas

Fig. 4 shows in perspective and partially intersected a superconducting cable with overcurrent protection according to the invention.

In Fig. 1 a superconducting cable is denoted by 1, said superconducting cable possibly, as known in the art, being constructed of a core, around which one or more layers of superconducting tapes is/are wound.

Current detectors 3, 4 are coupled to the ends of the cable, the current detectors having built-in circuit breakers or current limiters.
The current detectors may e.g. comprise superconducting pieces such as YBCO or Bi 2212 with built-in circuit breakers, and may be dimensioned such that they quench at a lower current than the superconductor of the actual cable, implying that if the current in the superconducting pieces exceeds a certain value, then the current to the superconducting cable will be broken after a short period of time.
By use of current limiters, the current will naturally be limited.
A hot shunt is coupled in parallel with a series connection of the superconducting pieces and the cable conductors of the superconducting cable, said shunt being ca-

pable of diverting the current supplied for a short period of time if the current detectors break the current or the current limiter limits the current.

Fig. 2 shows a more detailed embodiment of the superconducting cable according to the invention.

In this figure, 3,4 again denotes current and the reference number 7 denotes a superconducting cable.

A cold shunt is provided in parallel with the cable conductors of the cable, the shunt being denoted by the reference number 11. This shunt is cooled to the temperature of the superconductor. On the outside of this cold shunt is a cryostat 8, and on the outside thereof is an electrical insulation 9.

On the inside of the electrical insulation 9, an electrical conductor 10 is provided, which is made e.g. of copper and serves as a hot shunt at ambient temperature, cf. below.

The operation of the current detector in the superconducting cable will now be explained in greater detail with reference to the current plot of Fig. 3.

If it is ascertained that a current, which is too high, is flowing in the superconducting pieces 3, 4 the current will in a short time period flow in the cold shunt 11.

Then the current will be fed to the hot shunt 10, wherein the current will increase steeply as indicated by the broken line in Fig. 3 at the time 0.1s. At the same time, the current in the cold shunt 11 will decrease steeply.

Damage to the superconducting cable in the event that its superconductivity ceases can thus be avoided, which means that it becomes ohmic and consequently not capable of conducting the usual currents that can be conducted in the superconducting state.

Fig. 4 shows in perspective and partially intersected a superconducting cable as occurring in actual practice, which can be used in connection with the current protection as explained in connection with the preceding figures.

In this figure, 12 denotes a shield on the outside of which is a jacket 14. Inside the jacket is a dielectric insulator 15 surrounding an outer steel tube 16.
Inside the steel tube 16, spacers 17 are arranged that are supported by an aluminium foil 18 abutting an inner steel tube 19.
Inside the inner steel tube 19 a number of superconducting tapes 1 are wound around a hollow core 21.
The cooling of the superconducting tapes can be effected by supplying refrigerant to the channel 22 of the hollow core.

The reference number 11 denotes the position in which the cold shunt can be placed as explained above, whereas the reference number 24 denotes the position within the dielectric insulator, where the hot shunt can be placed.